Single-pulse Laser Heating Combined with Fast Optical Spectroscopy in Diamond Anvil Cells: Probing Materials Under Planetary Interior Conditions

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With the new high-brilliance x-ray sources, existing (e.g., LCLS) and coming online soon (NSLS, EXFEL), new possibilities of investigating matter at conditions approaching warm dense matter state are emerging. New technology will help in furthering knowledge of the states and properties of matter in interiors of planets which will impact understanding of the planetary composition and structure and also planetary history. Here I will address the needs of developing techniques for creating and probing extreme pressure-temperature (P-T) conditions that would be compatible with synchrotron X-ray probes.

The main focus is to determine the state, crystal and chemical structure, and thermochemical properties of materials under previously unattainable pressure-temperature conditions using static compression technique. Pressure has been generated in conventional diamond anvil cells (up to 200 GPa); the laser power is coupled to sample directly or through thin metallic pieces positioned in the high-pressure cavity. Pulsed-laser heating with microsecond to second's pulse duration has been utilized to reach temperatures of 2,000-15,000 K. To avoid extensive unwanted chemical reactivity and material diffusion the experiments are conducted in a single (or as small as possible number) event(s) during which material properties are measured and P-T are determined simultaneously. The duration of the experiment (few microseconds to several seconds) is chosen to collect sufficient signal or to follow fast time-dependent chemical/physical phenomena (e.g., thermal transport). Temperature is measured radiometrically in the time domain using a streak camera or intensified CCD detector.

I will present the results of several types of experiments at synchrotron beamlines (GSECARS and EC P02.22 at DESY) and in our optical laboratory at GL CIW. These are measurements of thermal expansion, melting, thermal conductivity, and optical properties (including mid infrared), and also synthesis of new material in extreme P-T conditions.